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Original

Safety Risk Assessment in Medical and Paramedical Education Laboratories

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Abstract

Background: Considering the reported positive effects of risk management practices and monitoring them by conducting risk assessments and achieving safety improvements, this study was conducted to assess the risks in the educational laboratories of Qom University of Medical Sciences. **Methods**: This cross-sectional study was conducted in 13 medical and paramedical educational laboratories. To assess safety conditions in the laboratories, a comprehensive safety checklist was developed, and in order to assess the risks of laboratories, a method called FMEA was used. Two trained occupational health and safety experts evaluated the laboratories understudy, identified the hazards, completed the relevant checklists, and subsequently ranked them based on severity, occurrence, and detection. Finally, a comparison was made based on the calculated Risk Priority Number (RPN) for each hazard. **Results**: In general, the fire hazards and electrical hazards of 54% of the laboratories have been accompanied by normal risk (RPN< 70), and nearly 8% of the laboratories had critical fire and electrical risks, including chemistry and immunology laboratories. In the case of equipment hazards, nearly 60% of the laboratories had critical or semi-critical risk levels. It is indicated that health exposure hazards were the most important hazards compared to the other ones. So that 61.5% of the laboratories had critical risk, and 15.3 % of them categorized as semi-critical risk. The highest RPN allocated to the biochemistry and chemistry laboratories (RPN>250). **Conclusion**: The results of this study showed that in general, three types of hazards, including health hazards, equipment, and material storage, should be given priority.

Keywords: Risk assessment; Safety Hazards; Failure mode & effects analysis (FMEA); Laboratory

Introduction

Laboratories have always played an important role in education and research in universities; Therefore, paying attention to the conditions and characteristics of these environments and providing the appropriate level of safety for them is of particular importance.[1, 2] Although laboratory environments seem clean and safe, due to the flammability and reactivity of various materials, the risk of spillage and splashing of liquids, the emission of explosive and flammable gases, electrical equipment, and the variety of laboratory activities, the safety risks in these environments are generally high.[3, 4] Besides, the physical, chemical, biological-infectious, ergonomic, and psychosocial hazards of laboratories are not less than other work environments.[5] Therefore, ensuring safety is always one of the essentials in educational laboratories,[6] and research laboratories in universities have many shortcomings

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and dangers, and there is a possibility of occurrence of various events and accidents in them.[3, 7]

Today, despite the relative improvement in safety levels in various laboratories, we still see many cases of dangerous and even fatal accidents. Many countries now have legislation on laboratory safety issues. Given the similar and scattered experiences in the country, risk identification in each laboratory is very important.[8] The International Maritime Organization (IMO) defines risk as a combination of the frequency and severity of the outcome. In other words, the hazard consists of two components: the probability of occurrence and the severity of the consequence. Control methods to reduce risk and monitoring corrective methods are among the issues that assessors should consider in the event of risk.[9] Accidents still occur despite ongoing efforts to reduce risk in various systems. From the point of view of safety, laboratories are of great importance due to the presence of various chemicals, electrical equipment, frequency of students and professors and staff who use its facilities, and the high values of some materials and equipment. On the other hand, the occurrence of adverse events is observed in many reports published by research centers; In 2009, the U.S. Bureau of Labor Statistics reported a rate of non-fatal occupational accident and disease events in medical and diagnostic laboratories at 2.8 per 200,000 hours worked.[10]

Therefore, it is necessary to identify, evaluate and control the risks in them using appropriate methods. Studies show that the possibility of occupational accidents in laboratories is high, for example, the explosion of a hydrogen capsule in the laboratory of Tarbiat Modares University of Tehran.[11, 12] To manage risks in laboratories, risk assessment has been introduced as an effective tool in identifying and controlling hazards.[13] These assessments will be the basis and requirement for control measures in the later stages of the risk management process. Over the past decades, many methods have been developed for scientific risk analysis, each of which has different perspectives, applications, and efficiencies. In this regard, various techniques such as Failure Mode and Effects Analysis (FMEA) can be used.[14-16] Considering the reported positive effects of risk management practices and monitoring them by conducting risk assessments and achieving safety improvements in software and hardware (staff and personal protective equipment facilities), it is important to investigate this issue. Therefore, considering the above and the existence of legal requirements to control hazards in the workplace, this study was conducted to assess the risks in the educational laboratories of Qom University of Medical Sciences.

Methods

Selected laboratories

This cross-sectional study was conducted in 13 medical and paramedical educational laboratories from 3 faculties (Medicine, Health and Dentistry) of Qom University of Medical Sciences (MUQ) in Iran. The laboratories were included Physiology, Pathology, Microbiology, Immunology, Parasitology, Biochemistry, Autopsy, Ergonomics, Chemical agents, Physical agents, and Chemistry. These laboratories were selected from the Medicine, Dentistry, and Health faculty of MUQ.

Hazards identification

To assess safety conditions in the laboratories, a comprehensive safety checklist was developed. The checklist was structured to cover safety hazards that might exist in medical or paramedical laboratories. The checklist integrated the available knowledge on this issue and provided a systematic safety assessment tool for these laboratories. It could also be used to provide a list of priorities for improving laboratory safety.Various references and international research agencies, including International Labour Organization (ILO), Occupational Safety and Health Administration (OSHA), and Health and Safety Executive (HSE), were consulted for developing the checklist.[11, 17] The checklist had 80 items in the five

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sections, including fire hazards (22 items), electrical hazards (14 items), equipment hazards (13 items), health exposure hazards (22 items), and storage safety hazards.[17] Each item was assessed as either provided (yes; score: 1) or not provided (no; score: 0). Two trained safety engineers fulfilled the checklists through observation and interviews with laboratory specialists and technical and installation personnel.

Risk assessment using FMEA

To assess the risks of laboratories, a method called FMEA was used FMEA "Failure Modes and Effect Analysis" is an analytical method that seeks to identify and rank as much as possible the potential risks and effects associated with them in the area where the risk assessment is performed. In other words, FMEA is a systematic process for identifying potential failures before they occur, which makes it possible to prioritize measures to reduce or eliminate destructive effects.[17] Generally, FMEA consists of two stages. The first step is to identify potential failure situations and their effects. The second step involves analyzing the sensitivity to determine the severity of the failure, which is done by evaluating and ranking the critical level of each failure.[18] In this method, three criteria are considered: the probability of occurrence of the hazard (O), the severity of the defect (S), and the probability of detection of the hazard before its occurrence (D). Multiplying these three criteria creates the Risk Priority Number (RPN).[19] To assess the risks, two trained occupational health and safety experts evaluated the laboratories understudy, identified the hazards, completed the relevant checklists, and subsequently ranked them based on severity, occurrence, and detection.

Severity (S)

The severity of the risk is the degree of seriousness (the effect of the potential risk) on the individual. There is a quantitative indicator of risk severity, expressed on a scale of 1 to 10.

Occurrence (O)

The probability of occurrence determines the frequency with which a potential cause or mechanism of danger occurs. Only by eliminating or reducing the causes or mechanism of each hazard can the number of occurrences be reduced. The probability of occurrence is measured on a scale of 1 to 10, as shown in Table 1. It is very useful to get a number related to the probability of occurrence, reviewing records, and examining control processes, standards, requirements, and labor laws and how they are applied.

Detection (D)

Ability to detect is a type of ability assessment to identify a cause/mechanism of occurrence of a hazard. In other words, the ability to detect danger before it occurs. Examining the control processes of the standards, labor requirements, and rules and how to apply them is very useful to achieve this number. Table 1 shows FMEA parameters on a scale of 1 to 10.[20]

Table1. Ratings for FMEA parameters

Rating	Probability		Severity	Detection
10	Very high: failure is Almost inevitable	⩾1.2	Hazardous without warning	Absolutely impossible
9		1.3	Hazardous with warning	Very remote
8	High: repeated failures	1.8	Very high	Remote
7		1.20	High	Very low
6	Moderate: Occasional failures	1.80	Moderate	Low
5		1.400	Low	Moderate
4		1.2000	Very low	Moderately high
3	Low: relatively few failures	1.15,000	Minor	High
2	Remote: failure is unlikely	1.150,000	Very minor	Very high
1		≤1.150,000	None	Almost certain

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Calculation of RPN

The risk priority number is the number resulting from multiplying three elements, including severity (S), probability (P), and detectability (D), and will be a number between 1 and 1000. So, failure and defects will be prioritized based on their number. The focus should then be on defects that have a higher RPN. RPN is an indicator of the separation of acceptable risk and unacceptable risk for the system.

Corrective measures

After determining the RPN, rank the risk based on the risk priority number. According to the RPN, the risk level is categorized into three groups:[21-24]

Normal level (RPN<70); where all three RPN elements (especially severity and probability of occurrence) are rated less than 5. In this condition, the corrective measure is not required.

Semi-critical level (70<RPN<140) where at least one of the three components of the RPN, in particular the severity and probability of occurrence, are rated higher than 5. In this case, corrective action is necessary.

Critical level (RPN>140), where at least two of the three RPN components are ranked higher than 5. In this situation, immediate corrective action is necessary.

Note: If the calculated RPN was less than 140, but each of the RPN components (severity, occurrence, and detection) was estimated at 10, the risk priority is considered a critical level. This is presented based on the results of other studies and tolerable risk criteria for the laboratory.[25] The tolerable risk in this study is determined based on human, economic and operational criteria.

According to RPN, various solutions can be proposed to reduce or eliminate the identified hazards, including eliminating the root causes of the hazard, reducing the severity of the defects, increasing the likelihood of risk detection in the process, and increasing employee satisfaction with the safety situation.

Results

This study was done to identify various hazards and associated risks in the medical and paramedical education laboratories at Qom University of medical sciences. The results of the study were presented based on the identified hazards, including fire, electrical, equipment, health exposure, and storage hazards in Tables 2 to 6, respectively. Besides, a comparison was made based on the calculated RPN for each hazard Fig.1. According to the results of Table 2, only in the Immunology laboratory, the fire risk was critical. The laboratories of Microbiology in the faculties of health and dentistry had the lower RPN. Generally, 54% of the studied laboratories had normal risk, and the risk levels of 39% and 7% of the laboratories were semi-critical and critical, respectively. Based on the electrical hazards Table 3, the laboratory of the chemistry in the health faculty was associated with the highest RPN (RPN=224), and the least RPN was for the Ergonomics laboratories (RPN=30). Similar percentages of risk levels were obtained for the electrical hazards, but the critical risk was observed for the Chemistry laboratory in the health faculty (RPN= 224).

In the case of equipment hazards, nearly 60% of the laboratories had critical or semi-critical risk levels.

Table 2. Risk priority related to fire hazards in different laboratories (Number of questions=22)

Faculty	Laboratory	S	O	D	RPN	Risk level
Dentistry	Microbiology	5	2	3	30	Normal
	Biochemistry	7	5	3	105	Semi-critical
Health	Chemical agents	7	3	3	63	Normal
	Chemistry	7	3	4	84	Semi-critical
	Microbiology	5	2	3	30	Normal
	Physical agents	5	3	4	60	Normal
	Ergonomics	4	3	4	48	Normal
Medicine	Pathology	6	5	3	90	Semi-critical
	Autopsy	6	5	2	60	Normal
	Microbiology	6	3	3	54	Normal
	Parasitology	6	4	4	96	Semi-critical
	Biochemistry	7	5	4	140	Semi-critical
	Immunology	6	6	4	144	Critical

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Although the probability of the detection and occurrence of the hazards related to the equipment was low or moderate, the severity of the potential risk was the most. So that in the chemistry laboratory in the health faculty and biochemistry laboratories in the dentistry and medicine faculties, the estimated severity number were ten and caused to put these laboratories in critical situations Table 4. Exposure health hazards were the highest risk levels among other identified hazards in the laboratories Table 5. 61.5% of the laboratories were recognized as a critical risk, and 15.3 % were semi-critical. The highest RPN allocated to the biochemistry and chemistry laboratories (RPN=288 and 252 for the biochemistry laboratories in the medicine and dentistry faculties, respectively, and RPN= 256 for the chemistry laboratory in the health faculties). Table 6, shows the risk priority related to storage safety in different laboratories. As the results show, minimum RPN values are for physical agents and ergonomic laboratories (RPN=4). This is the least RPN value estimated in this study. The chemistry and biochemistry laboratories had the most RPN values as 196 and 168, respectively.

Table 3. Risk priority related to electrical hazards in different laboratories (Number of questions=14)

Faculty	Laboratory	S	O	D	RPN	Risk level
Dentistry	Microbiology	5	7	3	105	Semi-critical
	Biochemistry	8	5	3	120	Semi-critical
Health	Chemical agents	7	4	2	56	Normal
	Chemistry	8	7	4	224	Critical
	Microbiology	5	4	3	60	Normal
	Physical agents	5	3	4	60	Normal
	Ergonomics	8	2	2	32	Normal
Medicine	Pathology	7	3	3	63	Normal
	Autopsy	5	5	2	50	Normal
	Microbiology	5	5	3	75	Normal
	Parasitology	6	5	3	90	Semi-critical
	Biochemistry	8	5	4	120	Semi-critical
	Immunology	6	6	3	108	Semi-critical

Table 4. Risk priority related to equipment hazards in different laboratories (Number of questions=13)

Faculty	Laboratory	S	O	D	RPN	Risk level
Dentistry	Microbiology	7	4	4	112	Semi-critical
	Biochemistry	10	2	4	80	Critical*
Health	Chemical agents	6	3	2	24	Normal
	Chemistry	10	3	4	120	Critical*
	Microbiology	7	2	3	44	Normal
	Physical agents	5	4	6	120	Semi-critical
	Ergonomics	3	7	3	63	Normal
Medicine	Pathology	5	4	3	60	Normal
	Autopsy	5	4	3	60	Normal
	Microbiology	7	5	4	140	Semi-critical
	Parasitology	5	4	4	80	Semi-critical
	Biochemistry	10	4	3	120	Critical*
	Immunology	6	6	4	144	Critical

*Refer to the note mentioned in section 2.3.5 of the method

Table 5. Risk priority related to health exposure hazards in different laboratories (Number of questions=22)

Faculty	Laboratory	S	O	D	RPN	Risk level
Dentistry	Microbiology	8	9	3	216	Critical
	Biochemistry	7	9	4	252	Critical
Health	Chemical agents	5	3	2	30	Normal
	Chemistry	8	8	4	256	Critical
	Microbiology	7	9	3	189	Critical
	Physical agents	2	1	4	8	Normal
	Ergonomics	2	1	2	4	Normal
Medicine	Pathology	6	6	3	108	Semi-critical
	Autopsy	5	6	4	120	Semi-critical
	Microbiology	7	8	3	168	Critical
	Parasitology	7	7	4	196	Critical
	Biochemistry	8	9	4	288	Critical
	Immunology	7	7	4	196	Critical

Table 6. Risk priority related to storage safety in different laboratories (Number of questions=17)

Faculty	Laboratory	S	O	D	RPN	Risk level
Dentistry	Microbiology	5	3	2	30	Normal
	Biochemistry	6	5	2	60	Normal
Health	Chemical agents	4	3	2	24	Normal
	Chemistry	7	7	4	196	Critical
	Microbiology	5	5	3	75	Semi-critical
	Physical agents	1	1	4	4	Normal
	Ergonomics	1	1	4	4	Normal
Medicine	Pathology	7	4	3	84	Semi-critical
	Autopsy	6	4	3	72	Semi-critical
	Microbiology	5	6	3	90	Semi-critical
	Parasitology	5	5	4	100	Semi-critical
	Biochemistry	7	8	3	168	Critical
	Immunology	6	5	4	120	Semi-critical

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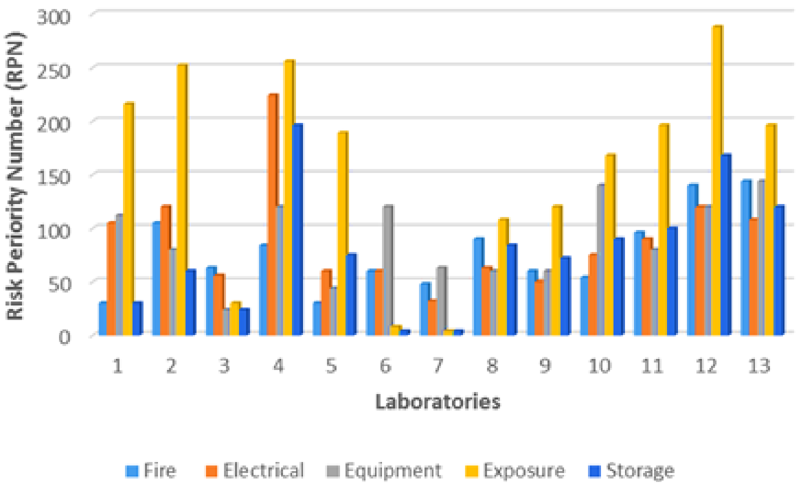

Figure 1. Comparison of the studied laboratories* based on RPN of the different hazards

*Studied laboratories	
1: Microbiology lab. in faculty of Dentistry	8: Pathology lab. in faculty of Medicine
2: Biochemistry lab. in faculty of Dentistry	9: Autopsy lab. in faculty of Medicine
3: Chemical agents' lab. in faculty of Health	10: Microbiology lab. in faculty of Medicine
4: Chemistry lab. in faculty of Health	11: Parasitology lab. in faculty of Medicine
5: Microbiology lab. in faculty of Health	12: Biochemistry lab. in faculty of Medicine
6: Physical agents' lab. in faculty of Health	13: Immunology lab. in faculty of Medicine
7: Ergonomics lab. in faculty of Health	

Discussion

This study was performed to recognized main laboratory-related hazards and associated risks in educational laboratories at Qom University of medical sciences. In general, fire hazards and electrical hazards of 54% of the laboratories have been accompanied by normal risk. In a fire risk assessment in the medical laboratories, Mirzaei et al. showed that existing protection measures provide only a sufficient level of protection for 35% of activities and 37% of buildings. However, no laboratory provides adequate protection for individuals, and fire safety training is recommended for staff.[7] In our study, nearly 8% of the laboratories had critical fire and electrical risks, including chemistry and immunology laboratories Table 2 and 3. In the case of equipment hazards, nearly 60% of the laboratories had critical or semi-critical risk levels. So that in the chemistry and biochemistry laboratories in the health and medicine faculties, the estimated severity number was 10 and caused to put these laboratories in critical situations Table 4. The results of the risk assessment performed in the laboratories of Yazd University of Medical Sciences showed that the main known deficiencies in the laboratories are related to management issues, and other shortcomings have been lack of proper ventilation, lack of heating and cooling systems in the laboratory, lack of instructions on safe work procedures and lack of physical space.[26]

The storage hazards and associated risks of 15.3 % of the laboratories were critical, and 46% and 38% had semi- critical and normal risk statuses. According to the obtained results, health exposure hazards were the most important hazards compared to the other ones. So that 61.5% of the laboratories had critical risk, and 15.3 % of them categorized as semi-critical risk. The highest RPN allocated to the biochemistry and chemistry laboratories (RPN>250). Health exposure hazards include staff or student exposure to the chemical, biological and/or radiological materials or sources in the laboratories. As shown in Table 5, the occurrence and the severity of related hazards

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in these laboratories were high. Employees in laboratories are exposed to different types of chemicals such as acids and bases, organic solvents, and alcohols; So far, several studies have been conducted to determine the level of exposure of employees working in hospital and laboratory environments.[27, 28] In a cohort study in Sweden, researchers found that the prevalence rate of mortality due to malignant cancers was very high. In addition, they found that leukemia among chemists who work with organic compounds in the laboratories at least a few years after graduation was very high.[29]

Malakouti et al. showed that the most frequent chemicals used were in microbiology laboratory with 12 chemicals, hematology with 11 cases, pathology with 9 cases, biochemistry with 6 cases, and hormonal pathology with 3 cases .[28] Despite the number of chemicals used, the conditions of exposure to chemicals such as physicochemical characteristics of materials, amount of material used and duration of exposure, and finally, the adequacy and utilization of control measures in laboratories are different in different laboratories. This is the reason for the difference in the final number of risks in our study. On the other hand, the risk assessment of the laboratories of physical agents and ergonomics in the health faculty showed that these laboratories had the least risk in all aspects of the studied laboratory-related hazards. So that, except for the semi-critical level of the risk for the equipment hazards in the case of physical agents, in the other ones, the levels of risks were assessed normal. In addition, among all the assessments performed, only in the case of equipment hazards, the number assigned to the severity of the probable hazards was determined to be 10 in some cases. Therefore, though the probability of occurrence and detection of these hazards was relatively low, the risk of this type of hazard was in the critical area. In a study aimed at risk assessment in the chemical laboratory, the results showed that of the 16 hazards identified in the chemistry laboratory, 81% were in the "high risk" range and 19% in the "low risk" range. The highest RPN was for electrical, chemical, ventilation, chemical waste, and fire hazards.[30]

Comparing the laboratories in different faculties showed that considering all aspects of the laboratory-related hazards, the chemical agents and ergonomics laboratories had the minimum safety risks. The risk levels for both of them were normal in all assessments. This is probably due to the new design and construction of these laboratories and the complete familiarity of the staff of these laboratories with safety and health issues. We found that 63% of laboratory experts have not experienced work-related retraining, focusing on safety issues. Undoubtedly, awareness can play an effective role in modulating people's behaviors.[31] One of the limitations of this study was the lack of attention to the type of activity of individuals in the laboratories (including laboratory experts, students, and instructors). Since the type of exposure of these people can affect the risk, especially the health exposure hazards, it is recommended to consider this in future studies.

Conclusion

This study showed that in general, three types of hazards, including health hazards, equipment, and material storage, should be given priority. The laboratories of chemical and biochemical have the higher risk priority numbers. The laboratories of immunology, parasitology, and microbiology are in the following priorities. It can be concluded from this study that three hazards, including health exposure, equipment, and storage hazards, contained 26% of the hazards in the laboratories under study. To control the identified risks, control programs and actions based on the hierarchy of elimination, replacement, engineering controls, management and application controls, and personal protective equipment are recommended.

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Conflict of interests

The authors declare that they have no conflict of interests.

Contribution of authors

All authors have the same contributions to the conception, design of the work, interpretation of data for the work, and final approval of the article.

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